all it is such non-predictable reactions as these that add so much to the interest of economic ornithology and convince us that however exact our scientific findings may be we can not expect the actions of living birds to conform to formulae.

U. S. Biological Survey,
Washington, D. C.

CURVATURE OF WING AND FLAPPING FLIGHT

BY WILLIAM BREWSTER TABER, JR.

In the last issue of the Wilson Bulletin (XLIV, 1932, pp. 19-22) my paper on "Curvature of Wing and Soaring Flight" gives in detail the explanation of the effect of the curvature of the wing and how the air currents striking the under wing surface are deflected, thus causing an upward lift and a thrust forward, in this way supplying the necessary power for soaring flight. In making this explanation clear it was necessary to resort to a velocity diagram involving technical terms. So as to avoid repetition here I will ask the interested reader to acquaint himself with the technical terms and their meanings as given in this previous paper.

In figure 17, upper diagram, I have represented by the heavy curved line *CD* the cross section of a wing of a bird flying to the left in a horizontal direction as indicated by the arrow above the diagram. We will consider in this case that the bird is flying in motionless air and that the wing is flapping straight downward. By bringing the wing straight downward the same effect is produced upon the wing as if the wing were held motionless and an air current were blowing straight upward against it. (Here let me say that to understand this problem it is essential to keep constantly in mind that the velocity lines represent the directions and velocities of air currents *in relation to the wing*, and not to the body or any other part of the bird or to an observer standing on the ground). The line *BC* represents this upward air current, the arrow on the line showing the direction, and the length of the line representing the velocity of this air current. Since the bird is flying horizontally to the left, the line *AB* has been drawn representing the current of air passing by the wing to the right. The resultant of the two components *AB* and *BC* is *AC*. In other words, the combined effects upon the wing of the two air currents, *AB* due to the motion of the bird to the left, and *BC* due to the motion of the wing downward, is equivalent to a single current blowing upon the wing in the direction *AC* and of a velocity proportional to the length of *AC*. In an ideal case this air current will just slide in under the front edge. swing around along the under surface of the wing and come off at the back edge in a direction tangential to the wing at *D* as shown by the line *DF*. As this is an ideal case loss of energy due to friction or eddying need not be considered, hence I have drawn *DF* exactly the same length as *AC*. The vertical component of *DF* is *DE*. Hence the total lifting effect upon the bird wing is proportional to the length of *BC* plus *DE*. Now it can readily be seen that *EF* is longer than *AB*. Since *EF* is longer than *AB*, or in other words since the horizontal velocity of the air current coming off the back edge of the wing is greater than the horizontal velocity of the air current coming in under the front edge of the wing there is a thrust forward, and the thrust forward is proportional to the difference in length of *EF* and *AB*. Consequently by bringing the wing sharply downward the bird produces a combination of air currents which, since they are deflected by the curved under surface of the wing, produce an upward lift which is opposed to the force of gravity, and a forward thrust which tends to move the bird forward. Whether or not successful flight is accomplished depends upon a number of other conditions such as the position of wing in relation to the various actual air currents, area of wing surface, weight, and other numerous factors.

No doubt by this time the reader has noticed that I have used a similar diagram and given a similar explanation in this paper on flapping flight to that which I did on soaring flight. It can readily be seen that this is perfectly justifiable, for in soaring flight when the wings are held motionless the bird is dependent upon upward moving air currents, while in flapping flight the bird obtains the same effect by bringing its wings sharply downward.

The Advantage of the Forward Downward Wing Stroke. It is common knowledge that birds in ordinary flapping flight not only bring their wings downward. but at the same time swing them forward. This may be easily observed by watching the slow flapping flight of any birds as large as, or larger than, the Crow. The rapidity of wing beat of smaller birds makes this observation upon them very difficult, or impossible, to the unaided eye. It is a fact that the effectiveness of the wing beat is greatly increased by this forward downward motion. I will, therefore. devote the remainder of this paper to explaining how this is.

We will now consider that the bird is flying under the same conditions as were given in the first part of this article, that is, to the left and in a horizontal direction and in still air, but with a forward downward wing stroke rather than with a straight downward wing stroke. In figure 17, lower diagram, *ACB* has been drawn exactly the same as in the upper diagram. The line *BC* represents the velocity of the air current acting on the wing caused by a straight downward wing beat. Line *AB* represents the velocity of the air current acting on the wing caused by the horizontal motion of the bird to the left. While *AC* is the resultant of these two. Now, in the upper diagram, anything that increases the resultant *AC* will also increase *DF* and hence will increase the vertical component *DE* and the horizontal component *EF*. If this increase is accomplished, since *DE* represents the vertical velocity of the air current coming off the back edge of the wing, the

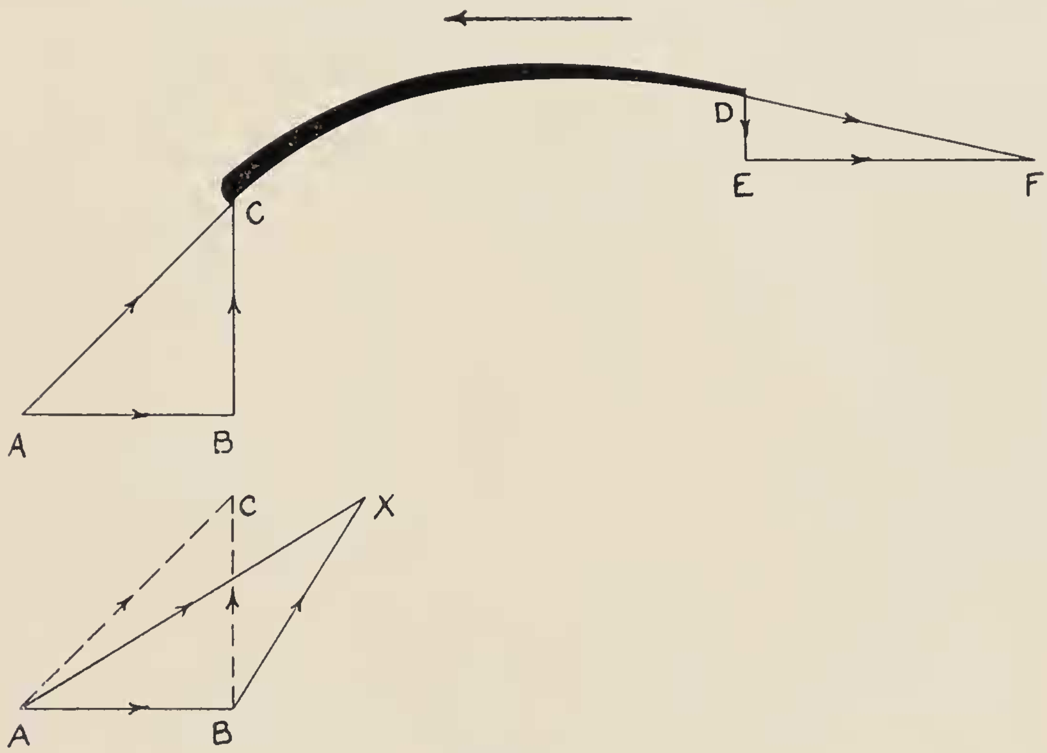

Fig. 17.

upward lift caused by the wing beat will be increased. Likewise since *EF* represents the horizontal velocity of the current of air coming off the back edge of the wing, the forward thrust will be increased.

Now the question is, will the forward downward wing beat increase the resultant *AC* and thus bring about all the attendant effects outlined above. In the lower diagram if, instead of drawing the component *BC* straight up as it would have to be in the case of a straight downward wing beat, we draw the corresponding component *BX* in the direction as shown, as it would have to be if the wing beat were forward and downward in the direction from *X* to *B*, then the resultant would be *AX*. It can be seen at a glance that *AX* is much longer than

AC, and therefore the resultant air current velocity would be much greater than in the case of the straight downward wing beat. Since with the forward downward wing beat the air would slip under the front edge of the wing with greater velocity it would also come off the back edge with greater velocity. So the downward horizontal and velocity components would be proportionately increased, and hence the lift upward and thrust forward would be increased.

This explains why the forward downward wing stroke is so much more effective than the straight downward wing stroke, and hence is the wing motion usually employed in flapping flight.

Greenwood Farm, Kansas, Illinois.

HARLAN'S HAWK*

BY NORMAN A. WOOD

Harlan's Hawk (*Buteo borealis harlani* (Audubon)) has interested me for many years past, but more so since I received my first specimen, taken May 1, 1916, in northeastern North Dakota by H. V. Williams, who has since that time sent me fifty more from the Red River Valley. From a small area in northwestern Arkansas I have added eighty more, and seven others from different states, or 137 in all. The last mentioned eighty-seven of these birds are all from the winter home of the species, and thirty birds have reached me in the flesh. These I have weighed and measured, and have made photographs of a few, showing the "peculiar" and "characteristic" markings of this fine bird.

Several years ago I noticed the plate of Harlan's Hawk by Audubon, and compared the figures with his description in the Ornithological Biography, 1831, pp. 442 and 443. He described an adult male (Birds of America, Pl. 86, Fig. 1) as having the tail "rather narrowly barred with brownish black." None of our adult birds have barred tails, so I agree with Taverner[1] that this bird was an immature one, probably a redtail. Audubon does not describe the adult female (Fig. 2 on same plate) but says that it resembles the male and measures twenty-two inches, which is about the same as twenty-two females measured by me in the flesh. I have examined Plate 86 carefully and find neither male nor female in adult plumage. I believe both are melanistic redtails. Both have the tails barred and both are entirely without white spots. Certainly neither one is the type as described by Sharpe. (In the British Catalogue of Birds, Vol. 1, 1874, p. 191).

---

*Read at the Detroit meeting, 1931, of the American Ornithologists' Union.
[1]Bulletin 48, Victoria Memorial Museum, p. 10. Ottawa, 1927.